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Mathematical Abilities in Elementary School Children with Autism Spectrum Disorder

Keywords: procedural calculation; number fact retrieval; word/language problems; time-related competences; elementary school; autism spectrum disorder

Abstract

Although clinical practitioners often express concerns about the mathematical functioning of children with autism spectrum disorder (ASD), the field of mathematics remains a relatively unexplored topic in individuals with ASD. Moreover, research findings are fragmentary and hold inconclusive results. The present study aimed to examine whether grade 1 (aged 6-7 years) to 4 (aged 9-10 years) elementary school children with ASD scored significantly different from age-adequate norms on mathematics. To this end, a multi-componential approach of mathematics was used. Four domains of mathematics were assessed in 121 children with ASD: procedural calculation, number fact retrieval, word/language problems, and time-related competences. All children attended general education classrooms, following the standard curriculum, and were coached by integrated educational services. Children with ASD showed a strength in word/language problems in second and fourth grade. There was evidence of a weakness for procedural calculation in first grade and for time-related competences in first and third grade. In all other cases, average scores were shown. As such, results revealed a profile of strengths, average abilities and weaknesses in mathematics and highlighted the importance of focusing on different domains of mathematics. Since a high variability in mathematical performance could be observed, we recommend an individual assessment when considering the mathematical trajectory of children with ASD.

1. Introduction

Despite the growing trend to include children with autism spectrum disorder (ASD) in general education settings (Harrower & Dunlap, 2001; Whitby & Mancil, 2009), the academic trajectory of these children does not always seem to run smoothly (Balfe, 2001; Lanou, Hough, & Powell, 2012). Within clinical practice, teachers and therapists often consider mathematics as one of the difficult subject matters for children with ASD (Department for Education and Skills, 2001; van Luit, Caspers, & Karelse, 2006). However, the domain of mathematics remains relatively unexplored as yet. Moreover, the few existing studies on mathematics in children with ASD hold inconclusive results.

First, several authors have put forward an enhanced mathematics performance in children with ASD compared to typically developing peers. Both anecdotal and descriptive research reported superior mathematical abilities in individuals with ASD (Baron-Cohen, Wheelwright, Burtenshaw, & Hobson, 2007; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001; Sacks, 1986), and also some empirical studies provided evidence that points in this direction (Iuculano et al., 2014; Jones et al., 2009). Jones et al. (2009), for example, demonstrated that an IQ-mathematics discrepancy in which mathematics exceeds general intellectual capacities (16.2% of the cases) is far more common than the opposite pattern (6.1% of the cases), suggesting a cognitive strength in mathematics. Iuculano et al. (2014) came to a similar conclusion when reporting better numerical problem solving skills in elementary school children with high-functioning autism than in typically developing peers.

In contrast, other studies have documented mathematical problems in children with ASD. A limited number of comorbidity studies (Mayes & Calhoun, 2006; Reitzel & Szatmari, 2003) showed that the prevalence of mathematical learning disorders (MLD) in children with ASD (varying from 12% to 46%) exceeded the prevalence of MLD in the general school-aged population, which is – although varying considerably depending on the criteria and measures (Mazzocco, 2007) – traditionally estimated between 2 and 14% (American Psychiatric Association [APA], 2013; Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005; Shalev, Manor, & Gross-Tsur, 2005). Moreover, several studies considered mathematics as a cognitive weakness, with a performance below cognitive abilities in a substantial subgroup of children with ASD (Chiang & Lin, 2007; Mayes & Calhoun, 2003). Mayes and Calhoun (2003) reported that 22% of the high-functioning individuals with ASD showed a significant IQ-math discrepancy. Chiang and Lin (2007) conducted a review which included 18 articles and found that performance on the Arithmetic subtest of the Wechsler Intelligence Scale (Wechsler, 1991) was significantly lower than the average of subtest scores, although they evaluated the clinical significance of the finding as being small.

The divergence in findings may, amongst others, be attributed to differences in focus (mathematical processes (e.g., Gagnon, Mottron, Bherer, & Joanette, 2004) versus outcomes [e.g., Chiang & Lin, 2007]), perspective (within-group (e.g., Mayes & Calhoun, 2003) versus between-group [e.g., Iuculano et al., 2014]), level of research (behavioural [e.g., Jones et al., 2009] versus neurobiological [e.g., Iuculano et al., 2014]), age (elementary school children [e.g., Iuculano et al., 2014) versus adolescents [e.g., Jones et al., 2009]), or reported mathematical abilities (composite score (e.g., Chiang & Lin, 2007) versus a multi-componential approach [e.g., Titeca, Roeyers, Josephy, Ceulemans, & Desoete, 2014]). Therefore, more research is warranted to disentangle the inconsistencies and to replicate previous findings on mathematics in children with ASD.

Although mathematics in elementary school is culturally dependent, several vital subcomponents seem to be involved in adequate mathematical development in elementary school (Geary, 2000). Based on the work of Geary (2000, 2004), four important domains can be identified: procedural calculation, number fact retrieval, word problems, and visuospatial abilities. *Procedural calculation* is needed to solve arithmetic problems, converting numerical information into mathematical equations and algorithms (Dowker, 2005). By executing arithmetic problems repetitively, basic number facts are retained in long-term memory and 'automatically' retrieved if needed, termed as *number fact retrieval* (Geary, 2000). The domain of word problems, in our study referred to as *word/language problems*, is associated with verbal problem solving abilities (Geary, 2000; Meyer, Salimpoor, Wu, Geary, & Menon, 2010). The role of language in the prediction of numeracy development has recently been stressed in several studies (e.g., Negen & Sarnecka, 2012; Praet, Titeca, Ceulemans, & Desoete, 2013) and recent research suggests that general language relates to early numeracy, with specific math language mediating this relationship (Toll, 2013). Finally, visuospatial abilities support many mathematical competences (Geary, 2004). One of those is the domain of *time-related competences* (Burny, Valcke, & Desoete, 2009; Eden, Wood, & Stein, 2003; Freedman, Leach, & Kaplan, 1994), which includes the abilities associated with measuring or recording time and incorporate aspects such as clock reading, calendar use, and measuring of time intervals (Burny et al., 2009).

Most studies on mathematical abilities of children with ASD only use a global composite score, failing to account for the componential nature of mathematics. As such, few hypotheses can be formulated regarding the performance of children with ASD on these different domains of mathematics. The procedural calculation and number fact retrieval abilities, sometimes termed calculation, computation or numerical operations, have been characterized from lower (Wei, Lenz, & Blackorby, 2013) to average (Minshew, Goldstein, Taylor, & Siegel, 1994; Titeca et al., 2014) or even better (Iuculano et al., 2014; Titeca et al., 2014) than those of typically developing children. Word/language problems, also termed applied problems, have been reported as a weaker (Minshew et al., 1994), average (Iuculano et al., 2014) or higher (Titeca et al., 2014) domain of mathematics compared to typically developing children. Finally, only one study looked into the time-related competences of children with ASD, reporting average performance in high-functioning children with ASD when compared to typically developing peers.

The present study aimed to examine whether grade 1 to 4 high-functioning elementary school children with ASD scored significantly different from age-adequate norms on four domains of mathematics: procedural calculation, number fact retrieval, word/language problems, and time-related competences. Since we observe a discrepancy between clinical reports and a limited number of studies, it is difficult to generate any hypotheses. Whereas teachers and therapists express their concerns about the mathematics performance of children with ASD (Department for Education and Skills, 2001; van Luit et al., 2006), between-group studies comparing mathematics performance in children with ASD and typically developing peers generally report average to enhanced scores (e.g., Chiang & Lin, 2007; Church, Alisanski, & Amanullah, 2000; Iuculano et al., 2014). Moreover, little (and inconsistent) evidence is available on the performance of children with ASD regarding the distinct domains of mathematics. As such, we wanted to contribute to a more balanced picture of the possible strengths and weaknesses of children with ASD in the field of mathematics when comparing them to typically developing peers.

2. Method

2.1 Participants and Procedure

The study included 31 first graders (6-7 years; 24 boys), 27 second graders (7-8 years; 23 boys), 39 third graders (8-9 years; 32 boys), and 24 fourth graders (9-10 years; 22 boys). The median age of the children was 7.83 years (*Interquartile range* = 1.84). All children previously received a formal diagnosis of ASD made independently by a qualified multidisciplinary team according to DSM-IV-TR criteria (APA, 2000). This formal diagnosis was confirmed by a score above the ASD cut-off (*T*-score > 60) on the Dutch version of the *Social Responsiveness Scale* (Roeyers, Thys, Druart, De Schryver, & Schittekatte, 2011).

All children were recruited through integrated educational services (Geïntegreerd ONderwijs [GON]; Flemish Ministry of Education and Training, 2013b), which provide individual support and coaching to children with developmental, learning or educational disabilities who attend general education classrooms. Ten out of 14 services which we contacted agreed to participate. In total, 375 children were asked to participate and the study had a response rate of 50,67% (*n* = 190). Of these 190 children, 121 met inclusion criteria.

GON-counselors were asked to provide IQ records of all pupils, because they have access to the clinical reports of the children they coach (i.e., clinical reports of all assessments in function of diagnosis). Such a clinical report is a necessary prerequisite for parents and their child to request for GON-counseling. However, in some clinical reports, no exact IQ-scores are mentioned, but only an interpretation of the results (i.e., of average intelligence). Children were tested between 5 and 9 years of age. Children were only included in the study if they were considered to be at least of average intelligence, either by displaying a full scale IQ (FSIQ) score above 80 (*n* = 101) or – if no exact figures were available – by clinically reported capacities of average intelligence (*n* = 20). The Hollingshead four factor index score (Hollingshead, 1975) was calculated as a measure of socio-economic status (SES), taking into account education, occupation, marital status, and sex. Table 1 provides an overview of the sample characteristics by grade level.

< Insert Table 1 about here >

Median scores on FSIQ and SES of the four grades did not differ significantly. However, there was a trend for a difference in the severity of autism spectrum symptoms, with children in grade 4 displaying a higher level of impairments in social responsiveness (see Table 1).

The participants were tested individually by their own GON-counselor from November 2012 till January 2013. All GON-counselors were trained in small groups during a two hour workshop to ensure a standardized assessment of the tasks. In this workshop, the test materials and procedure were demonstrated and discussed. A follow-up contact was organized to address any additional questions afterwards. The complete set of tests took approximately one hour and a half to administer. The assessment was spread over different testing sessions so as to fit within the duration of a counselling session (50 minutes).

Parental consent forms were obtained and the study protocol was approved by the ethical committee.

2.2 Materials

2.2.1 Autism symptom severity

The Dutch version of the *Social Responsiveness Scale* (*SRS*; Roeyers et al., 2011) is a continuous quantitative measure of autistic traits in 4- to 18-year-olds. This 65-item rating scale ascertains autistic symptoms across the entire range of severity in which they occur in nature, resulting in scores on five subscales: social awareness, social cognition, social communication, social motivation, and autistic preoccupations. An *SRS* total *T*-score between 60 and 75 indicates the presence of mild ASD or high functioning autism, while an *SRS* total *T*-score of over 75 indicates the presence of severe autism. The Dutch version of the *SRS* has a good internal consistency, with a Cronbach’s alpha of .94 for boys and .92 for girls (Roeyers et al., 2011).

2.2.2 Procedural calculation and word/language problems

The procedural calculation abilities as well as the word/language problem abilities of the children were tested using subtests of the *Cognitive Developmental Skills in Arithmetics* (*Cognitieve Deelhandelingen van het Rekenen* [*CDR*]; Desoete & Roeyers, 2006). All children completed the procedural subtest (including number splitting and addition/subtraction by regrouping exercises, presented in a number problem format; e.g., “12 – 9 = __”; *P*), the linguistic subtest (one-sentence word problems that can be solved by focusing on keywords, and hence, without mental representation; e.g. “1 more than 5 is__”; *L*), the mental representation subtest (one-sentence mathematical problems that go beyond a superficial approach of keywords and that require a mental representation to prevent number crunching errors such as answering “38” on the question “47 is 9 less than __”; *M*), and the contextual subtest (more than one-sentence word problems; e.g. “Wanda has 47 cards. Willy has 9 cards less than Wanda. How many cards does Willy have?”; *C*). Since students are more likely to miscomprehend a relational statement when the required arithmetic operation is inconsistent with the statement’s relational term – such as having to subtract when the relational term states *more than* – it was deemed important to make a distinction between the L-tasks and the M-tasks on one-sentence level (cf. Lewis & Mayes, 1987). As such, we could differentiate between simplicity (*L*) versus complexity (*C*) and tasks with (M) versus without (L) mental representation involved. In the current study, the test versions grade 1-2 and grade 3-4 of the *CDR* were used. Cronbach’s alphas were .93 and .91 for first and second grade respectively, and .89 for both third and fourth grade (Desoete & Roeyers, 2006).

2.2.3 Number fact retrieval

The *Arithmetic Number Facts Test* (*Tempotest Rekenen* [*TTR*]; De Vos, 1992) is a numerical facility test assessing the memorization and automatization of arithmetic facts. The

TTR consists of five subtests: addition, subtraction, multiplication, division, and mixed exercises. Participants were instructed to solve as many items as possible in five minutes; they could work one minute on every subtest. In first and second grade, the assessment was limited to the addition and subtraction exercises, as multiplications are only practiced and mastered at the end of second grade. The *TTR* showed good psychometric values in a study of 395 second graders with a Cronbach's alpha of .90 (Desoete, Ceulemans, De Weerdt, & Pieters, 2012).

2.2.4 Time-related competences

The Time Competence Test (*TCT*; *Test Tijdscompetentie*; Burny, 2012; Burny, Valcke, & Desoete, 2012) is developed to assess the mastery of time-related competences in elementary school children. The test consists of four domains: clock reading, time intervals, time-related word problems, and calendar use. The *TCT* consists of four parallel tests that are associated with the ability levels in each grade (grade 1, grade 2, grade 3, and grade 4-6). The items are each time based on the Flemish elementary mathematics curriculum of the specific grade(s). The *TCT-1* includes 14 items, the *TCT-2* includes 16 items, the *TCT-3* includes 33 items, and the *TCT-4-6* contains 32 items. Cronbach's alphas were .76 for the first grade, .61 for second grade, .90 for third grade, and .88 for fourth grade (Burny, 2012).

2.3 Analyses

First, an explorative correlation analysis was conducted to assess the linear relationships between mathematics and some sample characteristics. Next, analyses were conducted to compare the performance of the ASD children to the scores of the normed population sample. Since performance of the ASD group was compared with the predetermined norms of separate tests, one sample tests were used. In order to do so, z-scores for the children with ASD using the mean and standard deviation of the normed samples of the tests were calculated for the respective measures. As such, the null hypothesis stated that the mean scores of children with ASD were not significantly different from zero. Graphical inspection of the data revealed non-normal distributions for some of the variables. Hence, nonparametric tests were used for evaluation. In a first step, an overall independent samples median test was used to determine if any of the median z-scores for the four grades was statistically different from zero or not. This was done both for a general math index and for the four domains of mathematics separately. The general math index was calculated as the average of z-scores of the four separate domains of mathematics. It was added to the manuscript to get an impression of the overall mathematical abilities of children with ASD, in order to allow for comparison with previous research, which mostly uses one composite score. If a significant overall effect was found for the general math index or a particular domain of mathematics, a Wilcoxon signed rank test was conducted to determine in which of the four grades the performance differed significantly from zero. To control the overall type 1 error, a Bonferroni correction was applied for each of the four grades (i.e., *p*-values were assessed at the .013 level). Finally, the data were plotted to investigate the presence of possible subgroups or outliers in the ASD group. All analyses were performed in SPSS Version 21.0 (SPSS Inc, Chicago, IL).

3. Results

3.1 Bivariate Relations among The Constructs

Table 2 provides the correlations between the domains of mathematics and some sample characteristics.

< Insert Table 2 about here >

Correlations varied from $r = .21$ to $r = .56$ between the four domains of mathematics, justifying the use of a general math index. No significant correlations were found between mathematics and the severity of autism spectrum symptoms.

3.2 General Math Index

An independent samples median test indicated that the median z-scores were not significantly different from zero in any of the four grades, $\chi^2(3) = 6.09$, $p = .107$ (see Figure 1). As such, no further analyses for the separate grades were necessary.

< Insert Figure 1 and Figure 2 about here >

The plot of the general math index scores showed only few (1.67%) extreme scores (deviating more than two standard deviations from 0) and 83.34% of the scores were situated between one standard deviation below or above 0, suggesting that the results were comparable to the normed population (see Figure 2). Furthermore, the graph showed no evidence of distinct subgroups of children balancing out opposite scores.

3.3 Four Domains of Mathematics

An independent samples median test repeated for all four domains of mathematics was conducted to investigate whether at least one of the median z-scores of the four grades was significantly different from zero. This was the case in all domains of mathematics, except for number fact retrieval (see Table 3). Nevertheless, Figure 3 illustrates the performance per grade for all domains of mathematics.

< Insert Table 3 and Figure 3 about here >

For the domains in which a significant difference was found, Wilcoxon signed rank tests were executed per grade to reveal in which grades the median z-score deviated significantly from zero. For procedural calculation, children in the first grade scored significantly below average, *Mdn* = -0.98, $z = -2.60$, $p = .009$, $r = -.47$, whereas no significant (Bonferroni adjusted) differences could be found in the other grades. For word/language problems, no significant differences could be found in first and third grade. In contrast, children with ASD scored significantly above average on L-tasks in second grade, *Mdn* = 0.95, $z = 3.06$, $p = .002$, $r = .59$, and above average on L-tasks and C-tasks in fourth grade, respectively *Mdn* = -0.51, $z = 2.95$, $p = .003$, $r = .60$ and *Mdn* = 0.92, $z = 3.27$, $p = .001$, $r = .67$. For time-related competences, children with ASD scored significantly below average in first grade, *Mdn* = -0.35, $z = -3.42$, $p = .001$, $r = -0.63$, and in third grade, *Mdn* = -0.81, $z = -4.26$, $p = .000$, $r = -0.69$.

Finally, an in-depth analysis of individual differences on the separate mathematical domains showed plots that were very similar to that of the general math index scores, indicating only few extreme scores and no evidence of averaging out through subgroups of children.

4. Discussion

This study aimed at comparing procedural calculation, number fact retrieval, word/language problems, and time-related competences in first (6-7 years), second (7-8 years), third (8-9 years), and fourth (9-10 years) grade elementary school children with ASD to the normed population. General findings, limitations and implications of the study are provided below.

4.1 General Findings

First, small to large significant correlations were found between the different domains of mathematics (Cohen, 1988), meaning that all domains relate – in a greater or lesser extent – to each other. Although this finding makes analyses with a general math index possible, it is still warranted to consider the various mathematical domains separately (Dowker, 2008), as it gives rise to a more fine-tuned image of the mathematical abilities of individuals with ASD (cf. infra). In contrast, no significant correlations were found between mathematics and the severity of autism spectrum symptoms (in the domain of social responsiveness) in our homogenous group of GON children of average intelligence, which replicates previous findings (Jones et al., 2009).

Second, children with ASD show a poor start in procedural calculation in first grade, but seem to be able to regain the ground lost in the next grades. The suggestion (as the data are only cross-sectional in nature) of an evolution in performance might help to put the results of previous studies in a more developmental perspective. Our data suggest that the reported average or enhanced mathematical abilities of elementary school children with ASD in other studies (Chiang & Lin, 2007; Church et al., 2000; Iuculano et al., 2014) may not be present at the initial start of elementary school, but emerge perhaps only later on when children catch up. Since procedural calculation exercises and number fact problems bear a close resemblance to each other (both are presented in a number problem format), the question may arise as to why children with ASD only show problems with procedural calculation in first grade. Number fact retrieval appeals to rote memory and is taught systematically and straightforward within the Flemish curriculum (Domahs & Delazer, 2005). In contrast, procedural calculation requires further computational strategies and processes to solve the exercise (Domahs & Delazer, 2005). As such, more intuitive or implicit knowledge – which is less systematically taught and rehearsed – is essential to execute procedural calculation tasks. For instance, one has to find out why splitting numbers is beneficial for solving addition or subtraction by regrouping exercises. Although some previous studies reported difficulties with the grasping of implicit rules and assumptions in children with ASD (Gordon & Stark, 2007; Klinger & Dawson, 2001; Klinger, Klinger, & Pohlig, 2007), not everyone agrees with this line of reasoning, as some studies report intact implicit learning abilities in children with ASD (Barnes et al., 2008; Brown, Aczel, Jimenez, Kaufman, & Grant, 2010; Kourkoulou, Leekam, & Findlay, 2012) or propose other mechanisms that may have a negative impact on implicit learning without implicit learning itself being impaired (Brown et al., 2010). Moreover, it is important to be aware of the fact that “implicit learning” is often approached from a different angle in research (e.g., computerized tasks) than in real-world settings.

Third, children with ASD show age-adequate or superior performance on explicitly presented word/language problems, when formulated in short and clear sentences. Given the fact that at least a subgroup of children with ASD shows impaired structural language abilities (Boucher, 2012; Rapin, Dunn, Allen, Stevens, & Fein, 2009), one could have expected a poorer performance on word/language problems in some children, given the close relationship between general language and specific math language (Toll, 2013). However, our results are in accordance with the previously reported intact abilities to solve word/language problems in the study of Iuculano et al. (2014). In addition, the results show the importance of making a distinction between different kinds of word/language problems. When formulating clear sentences (*L*-tasks), without redundant or irrelevant information, children with ASD might even excel in solving word/language problems when compared to typically developing peers. This is even the case for more complex multiple-sentences ones (*C*-tasks), whereas exercises requiring mental representation (*M*-tasks) are within the average range. Future research should also include multiple-sentence word/language problems that require the use of mental representation, or word/language problems containing superfluous and irrelevant information.

Since children with ASD are known to have foremost difficulties with complex processes (Goldstein, Minshew, & Siegel, 1994; Minshew et al., 1994; Noens & van Berckelaer-Onnes, 2005), this higher complexity level may cause different results and could lead to a more fine-grained view on their performance.

Fourth, both first and third grade children with ASD showed a below average performance on the *Time Competence Test*. Time comprehension and clock reading is a complex matter that has proven to be difficult for all children (Burny et al., 2009; Monroe, Orme, & Erickson, 2002). However, due to its abstract and implicit nature and the absence of concrete representations (Foreman, Boyd-Davis, Moar, Korallo, & Chappell, 2008; Panagiotakopoulos & Ioannidis, 2002), it might even be more difficult for children with ASD to grasp our conventional time systems. The reason why the first and third grade might be particularly difficult, can perhaps be found in the Flemish math curriculum (Flemish Ministry of Education and Training, 2013a). In first grade, children get their first formal introduction in calendar use and clock reading, for which a new structured metric system has to be taught. Children learn to read the clock up until simple and half hour times. In second grade, children only learn to read quarter past or before times. In third grade, the digital format is introduced and children have to read the clock up until one minute precise, causing a large amount of new material to be presented at once. In the fourth grade, previous knowledge is rehearsed and further mastered. Children with ASD demonstrate difficulties with novelty processing and learning new or complex behaviours (Maes, Eling, Wezenberg, Vissers, & Kan, 2011; Minshew & Goldstein, 1998; Minshew et al., 1994), which may underlie the poorer performances in grade 1 and grade 3, as well as it may contribute to the poorer start in procedural calculation mentioned earlier.

4.2 Strengths and Limitations

Since previous studies on mathematics in children with ASD are scarce and results are inconclusive, the current study offers a valuable contribution to this field. The focus on different domains of mathematics has proven to be a meaningful approach, as performance seems to depend on the abilities that are assessed. In addition, the current study gives an initial impetus to take a more developmental perspective when assessing mathematics in children with ASD. In line with Goldstein et al. (1994), we agree that academic functioning of children with ASD may largely depend on the age at which the ability is assessed. Furthermore, the inclusion of a quite large group of children who follow the standard educational curriculum makes it possible to interpret the results of a comparison with the normed population more straightforward. Finally, all grades were comparable regarding FSIQ and SES. There was a trend towards a difference in autism symptom severity but given the non-significant correlations with mathematics, this could not provide an alternative explanation for the results.

However, the current findings should be placed in a context of some limitations. Although the results suggest a developmental evolution in procedural calculation, longitudinal research should be conducted to confirm the observed pattern. Next, although the examination of the plots of individual differences showed no evidence of substantial bias caused by outliers or the presence of subgroups, future research with still larger groups is needed in order to make cluster analysis possible. In addition, complementing a between-group perspective with a within-group perspective (in which different areas of functioning can be contrasted and compared to each other) would be of added value when further exploring the mathematical abilities of children with ASD. Finally, due to our homogenous sample of GON children of average intelligence, the conclusions of this study cannot be simply generalized to children in special educational settings or children of other intelligence levels. Although

GON-counseling is not intended to provide supplementary coaching/extra lessons concerning specific subject matters, it cannot be excluded that coaching for more domain-general abilities (concentration, planning, …) also has a positive influence on mathematical performance. As such, the results cannot also not be generalized to children who do not receive GON-counseling. Moreover, it would be preferable to administer an IQ test instead of using IQ data of clinical reports, because this would provide more comparable data for all children.

4.3 Educational Implications

Based on the findings of this study, some educational implications can be made regarding the mathematical trajectory of children with ASD in elementary school. First of all, for all four domains of mathematics that were assessed, children with ASD did not score significantly lower than age-adequate norms in grade 4. This suggests that, despite some difficulties in first and third grade, mathematics overall is not a persistent stumbling block for children with ASD. Therefore, it might not be desirable to implement general and large-scale interventions or adaptations to the currently used materials.

Although the findings of this study were not the result of the scores of two subgroups balancing each other out on average, still a large variation in scores was present. In this respect, children with ASD score as variable as typically developing children, making it impossible to provide a “prototypic” image of the math performance for all children with ASD. The current study supports the idea of making a thorough assessment of an individual’s strengths and weaknesses in order to stipulate appropriate educational guidelines. Based on this profile, one could build on strengths to urge improvement in other, more difficult, domains of mathematics (Jones et al., 2009).

Furthermore, our findings indicate that autism-specific information processing characteristics might influence mathematics performance. The fact that children with ASD showed weaker results in procedural calculation in first grade and on time-related competences in first and third grade, is in line with reports of difficulties with the introduction of new, implicit, or complex information (Courchesne, Lincoln, Kilman, & Galambos, 1985; Gomot & Wicker, 2012; Klinger et al., 2007; Maes et al., 2011; Minshew & Goldstein, 1998; Minshew et al., 1994). The fact that at group level, average to high scores were observed for word/language problems compared to the normed samples, might also be related to this aspect. All word/language problems were operationalized as relatively short, concise, and straightforward tasks. It is, however, possible that high-functioning children with ASD perform as well as typically developing peers, as long as the difficulty level does not exceed a certain threshold of complexity, a suggestion previously formulated by Goldstein et al. (1994).

Therefore, we recommend teachers and clinicians to be attentive for the possible impact of these autism-specific information processing characteristics. Children with ASD might need more time to process information and to deal with new or complex information (e.g., Happe, 1999; Minshew & Goldstein, 1998). It seems for example plausible that a more direct teaching approach is needed in children with ASD, an approach in which the underlying lines of reasoning are addressed explicitly before they understand the usefulness of certain strategies or procedures or before they can apply the procedures correctly. When following the line of thought that other mechanisms have a negative impact upon implicit learning, one could also try to pay attention to these factors, such as the overuse of explicit strategies, the attentional focus, or the offline learning and atypical consolidation of acquired knowledge (Brown et al., 2010).

Moreover, it will be important to not only focus on current outcomes, but also to closely monitor and evaluate the learning process of an individual child on these domains. It can be helpful to keep track of the changing needs of a child, as well as to keep in mind the specific demands of the math curriculum. When doing so, it may in some cases be possible to judge beforehand when additional guidance will be needed. Revealing more closely the exact impact of these autism-specific information processing characteristics is therefore a promising path for future research to take.

To summarize, elementary school children with ASD show a profile of strengths, average abilities and weaknesses in mathematics. Based on our findings, it is recommended that future research takes into account several domains of mathematics. Furthermore, one should be aware of the autism-specific information processing difficulties that might influence academic functioning when further exploring this topic. Finally, it will be important to look at individual strengths and weaknesses when following up the mathematical trajectory of children with ASD.

Conflict of interest statement

The authors state no conflict of interest in the current study.

References

American Psychiatric Association [APA]. (2013). *Diagnostic and statistical manual of mental disorders (5th ed.)*. Arlington, VA: American Psychiatric Publishing.

APA. (2000). *Diagnostic and statistical manual of mental disorders (4th ed., text revision)*. Washington, DC: Author.

Balfe, P. (2001). A study of the induction experiences and the needs of teachers new to autistic spectrum disorders in the Republic of Ireland. *Good Autism Practice Journal, 2*, 75-85.

Barbaresi, W. J., Katusic, S. K., Colligan, R. C., Weaver, A. L., & Jacobsen, S. J. (2005). Math learning disorder: Incidence in a population-based birth cohort, 1976-82, Rochester, Minn. *Ambulatory Pediatrics, 5*, 281-289. http://dx.doi.org/10.1367/a04-209r.1

Barnes, K. A., Howard, D. V., Howard, J. H., Gilotty, L., Kenworthy, L., Gaillard, W. D., & Vaidya, C. J. (2008). Intact implicit learning of spatial context and temporal sequences in childhood autism spectrum disorder. *Neuropsychology, 22*, 563-570. http://dx.doi.org/10.1037/0894-4105.22.5.563

Baron-Cohen, S., Wheelwright, S., Burtenshaw, A., & Hobson, E. (2007). Mathematical talent is linked to autism. *Human Nature-an Interdisciplinary Biosocial Perspective, 18*, 125-131. http://dx.doi.org/10.1007/s12110-007-9014-0

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The autism-spectrum quotient (AQ): Evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders, 31*, 5-17. http://dx.doi.org/10.1023/a:1005653411471

Boucher, J. (2012). Research Review: Structural language in autistic spectrum disorder - characteristics and causes. *Journal of Child Psychology and Psychiatry, 53*, 219-233. http://dx.doi.org/10.1111/j.1469-7610.2011.02508.x

Brown, J., Aczel, B., Jimenez, L., Kaufman, S. B., & Grant, K. P. (2010). Intact implicit learning in autism spectrum conditions. *Quarterly Journal of Experimental Psychology, 63*, 1789-1812. http://dx.doi.org/ 10.1080/17470210903536910

Burny, E. (2012). *Time-related competences in primary education (Doctoral dissertation).* Ghent University, Ghent.

Burny, E., Valcke, M., & Desoete, A. (2009). Towards an agenda for studying learning and instruction focusing on time-related competences in children. *Educational Studies, 35*, 481-892. http://dx.doi.org/10.1080/03055690902879093

Burny, E., Valcke, M., & Desoete, A. (2012). Clock reading: an underestimated topic in children with mathematics difficulties. *Journal of Learning Disabilities, 45*, 352-361. http://dx.doi.org/10.1177/0022219411407773

Chiang, H. M., & Lin, Y. H. (2007). Mathematical ability of students with Asperger syndrome and high-functioning autism - A review of literature. *Autism, 11*, 547-556. http://dx.doi.org/10.1177/1362361307083259

Church, C., Alisanski, S., & Amanullah, S. (2000). The social, behavioral, and academic experiences of children with Asperger syndrome. *Focus on Autism and Other Developmental Disabilities, 15*, 12. http://dx.doi.org/10.1177/108835760001500102

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences (2nd ed.)*. New Jersey: Lawrence Erlbaum Associates.

Courchesne, E., Lincoln, A. J., Kilman, B. A., & Galambos, R. (1985). Event-related brain potential correlates of the processing of novel visual and auditory information in autism. *Journal of Autism and Developmental Disorders, 15*, 55-76. http://dx.doi.org/10.1007/BF01837899

De Vos, T. (1992). *Tempo Test Rekenen (TTR) [Arithmetic Number Facts Test]*. Nijmegen: Berkhout.

Department for Education and Skills. (2001). *The daily mathematics lesson: Guidance to support pupils with autism spectrum disorders*. London: DfES Publications.

Desoete, A., Ceulemans, A., De Weerdt, F., & Pieters, S. (2012). Can we predict mathematical learning disabilities from symbolic and non-symbolic comparison tasks in kindergarten? Findings from a longitudinal study. *British Journal of Educational Psychology, 82*, 64-81. http://dx.doi.org/10.1348/2044-8279.002002

Desoete, A., & Roeyers, H. (2006). *Cognitieve Deelhandelingen van het Rekenen (CDR). Handleiding & testprotocol [Cognitive Developmental skills in Arithmetics. Manual & testprotocol]*. Herenthals: VVL.

Domahs, F., & Delazer, M. (2005). Some assumptions and facts about arithmetic facts. *Psychology Science, 47*, 96-111.

Dowker, A. (2005). *Individual differences in arithmetic: Implications for psychology, neuroscience and education*. Hove: Psychology Press.

Dowker, A. (2008). Individual differences in numerical abilities in preschoolers. *Developmental Science, 11*, 650-654. http://dx.doi.org/10.1111/j.1467-7687.2008.00713.x

Eden, G. F., Wood, F. B., & Stein, J. F. (2003). Clock drawing in developmental dyslexia. *Journal of Learning Disabilities, 36*, 216-228. http://dx.doi.org/10.1177/002221940303600302

Flemish Ministry of Education and Training. (2013a). Curricula. Retrieved October 1, 2013, from http://www.ond.vlaanderen.be/infolijn/faq/leerplannen/

Flemish Ministry of Education and Training. (2013b). Special educational needs. Retrieved October 1, 2013 from http://www.ond.vlaanderen.be/specifieke-onderwijsbehoeften/bao/gon/

Foreman, N., Boyd-Davis, S., Moar, M., Korallo, L., & Chappell, E. (2008). Can virtual environments enhance the learning of historical chronology? *Instructional Science, 36*, 155-173. http://dx.doi.org/10.1007/s11251-007-9024-7

Freedman, M., Leach, L., & Kaplan, E. (1994). *Clock drawing: A neuropsychological analysis*. New York: Oxford University Press.

Gagnon, L., Mottron, L., Bherer, L., & Joanette, Y. (2004). Quantification judgement in high functioning autism: Superior or different? *Journal of Autism and Developmental Disorders, 34*, 679-689. http://dx.doi.org/10.1007/s10803-004-5288-9

Geary, D. C. (2000). From infancy to adulthood: the development of numerical abilities. *European Child & Adolescent Psychiatry, 9*, 11-16. http://dx.doi.org/10.1007/s007870070004

Geary, D. C. (2004). Mathematics and learning disabilities. *Journal of Learning Disabilities, 37*, 4-15. http://dx.doi.org/10.1177/00222194040370010201

Goldstein, G., Minshew, N. J., & Siegel, D. J. (1994). Age differences in academic achievement in high-functiong autistic individuals. *Journal of Clinical and Experimental Neuropsychology, 16*, 671-680. http://dx.doi.org/10.1080/01688639408402680

Gomot, M., & Wicker, B. (2012). A challenging, unpredictable world for people with Autism Spectrum Disorder *International Journal of Psychophysiology, 83*, 240-247. http://dx.doi.org/10.1016/j.ijpsycho.2011.09.017

Gordon, B., & Stark, S. (2007). Procedural learning of a visual sequence in individuals with autism. *Focus on Autism & Other Developmental Disabilities, 22*, 14-22. http://dx.doi.org/10.1177/10883576070220010201

Happe, F. (1999). Autism: cognitive deficit or cognitive style? *Trends in Cognitive Sciences, 3*, 216-222. http://dx.doi.org/10.1016/s1364-6613(99)01318-2

Harrower, J. K., & Dunlap, G. (2001). Including children with autism in general education classrooms - A review of effective strategies. *Behavior Modification, 25*, 762-784. http://dx.doi.org/10.1177/0145445501255006

Hollingshead, A. B. (1975). *Four factor index of social status.* New Haven, CT: Yale University.

Iuculano, T., Rosenberg-Lee, M., Supekar, K., Lynch, C. J., Khouzam, A., Phillips, J., . . . Menon, V. (2014). Brain organization underlying superior mathematical abilities in children with autism. *Biological Psychiatry, 75*, 223-230. http://dx.doi.org/10.1016/j.biopsych.2013.06.018

Jones, C. R. G., Happe, F., Golden, H., Marsden, A. J. S., Tregay, J., Simonoff, E., . . . Charman, T. (2009). Reading and arithmetic in adolescents with autism spectrum disorders: Peaks and dips in attainment. *Neuropsychology, 23*, 718-728. http://dx.doi.org/10.1037/a0016360

Klinger, L. G., & Dawson, G. (2001). Prototype formation in autism. *Development and Psychopathology, 13*, 111-124. http://dx.doi.org/10.1017/s0954579401001080

Klinger, L. G., Klinger, M. R., & Pohlig, R. L. (2007). Implicit learning impairments in autism spectrum disorders: implications for treatment. In J. M. Perez, P. M. Gonzalez, M. L. Comi & C. Nieto (Eds.), *New developments in autism: The future is today* (pp. 75-102). London: Kingsley Press.

Kourkoulou, A., Leekam, S. R., & Findlay, J. M. (2012). Implicit learning of local context in autism spectrum disorder. *Journal of Autism and Developmental Disorders, 42*, 244-256. http://dx.doi.org/10.1007/s10803-011-1237-6

Lanou, A., Hough, L., & Powell, E. (2012). Case studies on using strengths and interests to address the needs of students with autism spectrum disorders. *Intervention in School and Clinic, 47*, 175-182. http://dx.doi.org/10.1177/1053451211423819

Maes, J. H. R., Eling, P., Wezenberg, E., Vissers, C., & Kan, C. C. (2011). Attentional set shifting in autism spectrum disorder: Differentiating between the role of perseveration, learned irrelevance, and novelty processing. *Journal of Clinical and Experimental Neuropsychology*, 210-217. http://dx.doi.org/10.1080/13803395.2010.501327

Mayes, S. D., & Calhoun, S. L. (2003). Analysis of WISC-III, Stanford-Binet : IV, and academic achievement test scores in children with autism. *Journal of Autism and Developmental Disorders, 33*, 329-341. http://dx.doi.org/10.1023/a:1024462719081

Mayes, S. D., & Calhoun, S. L. (2006). Frequency of reading, math, and writing disabilities in children with clinical disorders. *Learning and Individual Differences, 16*, 145-157. http://dx.doi.org/10.1016/j.lindif.2005.07.004

Mazzocco, M. M. M. (2007). Defining and differentiating mathematical learning disabilities and difficulties. In D. B. Berch & M. M. M. Mazzocco (Eds.), *Why is math so hard for some children? The nature and origins of mathematical learning difficulties and disabilities* (pp. 29-48). Baltimore: MD: Paul H. Brookes Publishing Co.

Meyer, M. L., Salimpoor, V. N., Wu, S. S., Geary, D. C., & Menon, V. (2010). Differential contribution of specific working memory components to mathematics achievement in 2nd and 3rd graders. *Learning and Individual Differences, 20*, 101-109. http://dx.doi.org/10.1016/j.lindif.2009.08.004

Minshew, N. J., & Goldstein, G. (1998). Autism as a disorder of complex information processing. *Mental Retardation and Developmental Disabilities Research Reviews, 4*, 129-136. http://dx.doi.org/10.1002/(sici)1098-2779(1998)4:2<129::aid-mrdd10>3.0.co;2-x

Minshew, N. J., Goldstein, G., Taylor, H. G., & Siegel, D. J. (1994). Academic achievement in high-functioning autistic individuals. *Journal of Clinical and Experimental Neuropsychology, 16*, 261-270. http://dx.doi.org/10.1080/01688639408402637

Monroe, E. E., Orme, M. P., & Erickson, L. B. (2002). Working cotton: toward an understanding of time. *Teaching children mathematics*, *8*, 475-479.

Negen, J., & Sarnecka, B. W. (2012). Number-concept acquisition and general vocabulary development. *Child Development, 83*, 2019-2027. http://dx.doi.org/10.1111/j.1467-8624.2012.01815.x

Noens, I. L. J., & van Berckelaer-Onnes, I. A. (2005). Captured by details: sense-making, language and communication in autism. *Journal of Communication Disorders*, *38,* 123-141. http://dx.doi.org/10.1016/j.jcomdis.2004.06.002

Panagiotakopoulos, C. T., & Ioannidis, G. S. (2002). Assessing children's understanding of basic time concepts through multimedia software. *Computers & Education*, *38*, 331–349. http://dx.doi.org/10.1016/S0360-1315(01)00066-5

Praet, M., Titeca, D., Ceulemans, A., & Desoete, A. (2013). Language in the prediction of arithmetics in kindergarten and grade 1. *Learning and Individual Differences*, *27*, 90-96. http://dx.doi.org/10.1016/j.lindif.2013.07.003

Rapin, I., Dunn, M. A., Allen, D. A., Stevens, M. C., & Fein, D. (2009). Subtypes of language disorders in school-age children with autism. *Developmental Neuropsychology*, *34*, 66-84. http://dx.doi.org/10.1080/87565640802564648

Reitzel, J., & Szatmari, P. (2003). Cognitive and academic problems. In M. Prior (Ed.), *Learning and behavior problems in Asperger syndrome* (pp. 35-54). New York: Guilford Press.

Roeyers, H., Thys, M., Druart, C., De Schryver, M., & Schittekatte, M. (2011). *SRS Screeningslijst voor autismespectrum stoornissen [SRS Screening list for autism spectrum disorders]*. Amsterdam: Hogrefe.

Sacks, O. (1986). *The man who mistook his wife for a hat*. Basingstoke & Oxford: Picador.

Shalev, R. S., Manor, O., & Gross-Tsur, V. (2005). Developmental dyscalculia: a prospective six-year follow-up. *Developmental Medicine and Child Neurology, 47*, 121-125. http://dx.doi.org/10.1017/s0012162205000216

Titeca, D., Roeyers, H., Josephy, H., Ceulemans, A., & Desoete, A. (2014). Preschool predictors of mathematics in first grade children with autism spectrum disorder. *Research in Developmental Disabilities*. http://dx.doi.org/10.1016/j.ridd.2014.07.012

Toll, S. (2013). *A journey towards mathematics - Effects of remedial education on early numeracy (Doctoral dissertation).* Utrecht University, Utrecht.

van Luit, J. E. H., Caspers, M., & Karelse, A. (2006). Voorbereidende rekenvaardigheden van kinderen met een autisme spectrumstoornis [Preparatory arithmetic abilities of children with autism spectrum disorder]. In D. Van der Aalsvoort (Ed.), *Ontwikkelen ingewikkeld? Vormen van diagnostiek en behandeling van gedragsproblemen bij jonge kinderen* (pp. 97-110). Amsterdam: SWP.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children–Third Edition*. San Antonio, TX: Psychological Corporation.

Wei, X., Lenz, K. B., & Blackorby, J. (2013). Math growth trajectories of students with disabilities: Disability category, gender, racial, and socioeconomic status differences from ages 7 to 17. *Remedial and Special Education*, *34*, 154-165. http://dx.doi.org/10.1177/0741932512448253

Whitby, P. J. S., & Mancil, G. R. (2009). Academic achievement profiles of children with high functioning autism and Asperger syndrome: A review of the literature. *Education and Training in Developmental Disabilities, 44*, 551-560.

Table 1

Descriptive characteristics of the sample.

	M	*(SD)*	*Min*	*Max*	*Kruskal-Wallis H test*
Age					$\chi^2(3) = 111.72$, $p < .001$
Grade 1 ($n = 31$)	6.36	(0.24)	5.92	6.83	
Grade 2 ($n = 27$)	7.38	(0.26)	6.83	7.75	
Grade 3 ($n = 39$)	8.28	(0.31)	7.75	8.75	
Grade 4 ($n = 24$)	9.28	(0.30)	8.83	9.75	
FSIQ[a]					$\chi^2(3) = 1.80$, $p = .616$
Grade 1 ($n = 27$)	102.67	(12.31)	81.00	129.00	
Grade 2 ($n = 21$)	104.19	(15.41)	83.00	133.00	
Grade 3 ($n = 32$)	107.16	(13.80)	84.00	147.00	
Grade 4 ($n = 21$)	105.62	(13.57)	80.00	129.00	
SES[b]					$\chi^2(3) = 3.47$, $p = .325$
Grade 1 ($n = 31$)	40.29	(12.12)	12.00	58.00	
Grade 2 ($n = 27$)	40.91	(13.03)	13.50	60.50	
Grade 3 ($n = 38$)	44.38	(11.76)	8.00	63.00	
Grade 4 ($n = 24$)	43.85	(11.55)	22.00	63.00	
SRS[c]					$\chi^2(3) = 7.29$, $p = .063$
Grade 1 ($n = 31$)	84.23	(18.54)	63.00	130.00	
Grade 2 ($n = 27$)	86.07	(17.95)	62.00	129.00	
Grade 3 ($n = 39$)	88.46	(16.80)	61.00	132.00	
Grade 4 ($n = 24$)	95.04	(15.97)	61.00	126.00	

Note. [a]Full scale IQ; [b]Socio-economic status, measured with Hollingshead four factor index; [c]*T*-score on the *Social Responsiveness Scale*

Table 2

Correlations between domains of mathematics and sample characteristics.

	Procedural calculation	Word/language problems			Number fact retrieval	Time related competences	SES[d]	FSIQ[e]	*SRS*[f]
		L [a]	*M* [b]	*C* [c]					
Procedural calculation	-	-	-	-	-	-	-	-	-
Word/language problems									
L-tasks[a]	.30**	-	-	-	-	-	-	-	-
M-tasks[b]	.27**	.47**	-	-	-	-	-	-	-
C-tasks[c]	.56**	.48**	.52**	-	-	-	-	-	
Number fact retrieval	.48**	.25**	.21*	.43**	-	-	-	-	-
Time related competences	.34**	.32**	.38**	.41**	.37**	-	-	-	-
SES[d]	.29*	.21*	.17	.26*	.27*	.12	-	-	-
FSIQ[e]	.40**	.35**	.50**	.43**	.19	.26*	.22*	-	-
SRS[f]	.07	-.04	-.00	.03	.03	.05	-.01	.05	-

Note. *$p < .05$, ** Bonferroni-corrected ($p < .001$). [a]Linguistic tasks, [b]Mental representation tasks, [c]Contextual tasks, [d]Socio-economic status, [e]Full scale IQ, [f]Raw score on *Social Responsiveness Scale*.

Table 3

Descriptive characteristics of the outcome measures.

	ASD					Independent samples median test
	N	*M*	*(SD)*	*Min*	*Max*	
Procedural calculation						$\chi^2(3) = 20.58$, $p < .001$
Grade 1	31	-0.64	(0.97)	-1.79	1.45	
Grade 2	27	0.28	(0.69)	-1.57	0.84	
Grade 3	38	0.25	(0.97)	-2.78	1.84	
Grade 4	24	0.05	(0.76)	-1.52	0.88	
Word/language problems: L-tasks[a]						$\chi^2(3) = 9.36$, $p = .025$
Grade 1	31	0.29	(1.31)	-1.47	2.64	
Grade 2	27	0.71	(0.95)	-1.71	1.48	
Grade 3	38	0.15	(0.86)	-2.83	0.72	
Grade 4	24	0.25	(0.63)	-1.98	0.51	
Word/language problems: M-tasks[b]						$\chi^2(3) = 10.96$, $p = .012$
Grade 1	31	0.27	(1.38)	-0.83	3.48	
Grade 2	27	-0.29	(1.24)	-1.82	1.79	
Grade 3	38	0.20	(1.03)	-1.68	1.34	
Grade 4	24	-0.19	(1.24)	-2.77	0.79	
Word/language problems: C-tasks[c]						$\chi^2(3) = 17.49$, $p = .001$
Grade 1	31	-0.12	(1.19)	-1.59	2.61	
Grade 2	27	0.23	(0.73)	-0.95	1.32	
Grade 3	38	0.17	(0.95)	-2.63	1.14	
Grade 4	24	0.47	(0.76)	-2.18	0.92	
Number fact retrieval						$\chi^2(3) = 3.16$, $p = .367$
Grade 1	31	-0.30	(1.17)	-2.15	2.81	
Grade 2	27	-0.17	(0.91)	-1.68	1.44	
Grade 3	39	0.11	(0.99)	-1.81	2.62	
Grade 4	22	0.21	(1.04)	-1.52	2.25	
Time-related competences						$\chi^2(3) = 9.78$, $p = .021$
Grade 1	30	0.93	(0.93)	-2.39	2.39	
Grade 2	27	-0.34	(1.07)	-2.23	1.86	
Grade 3	38	-0.60	(0.67)	-1.66	0.65	
Grade 4	23	-0.26	(1.09)	-2.66	1.23	

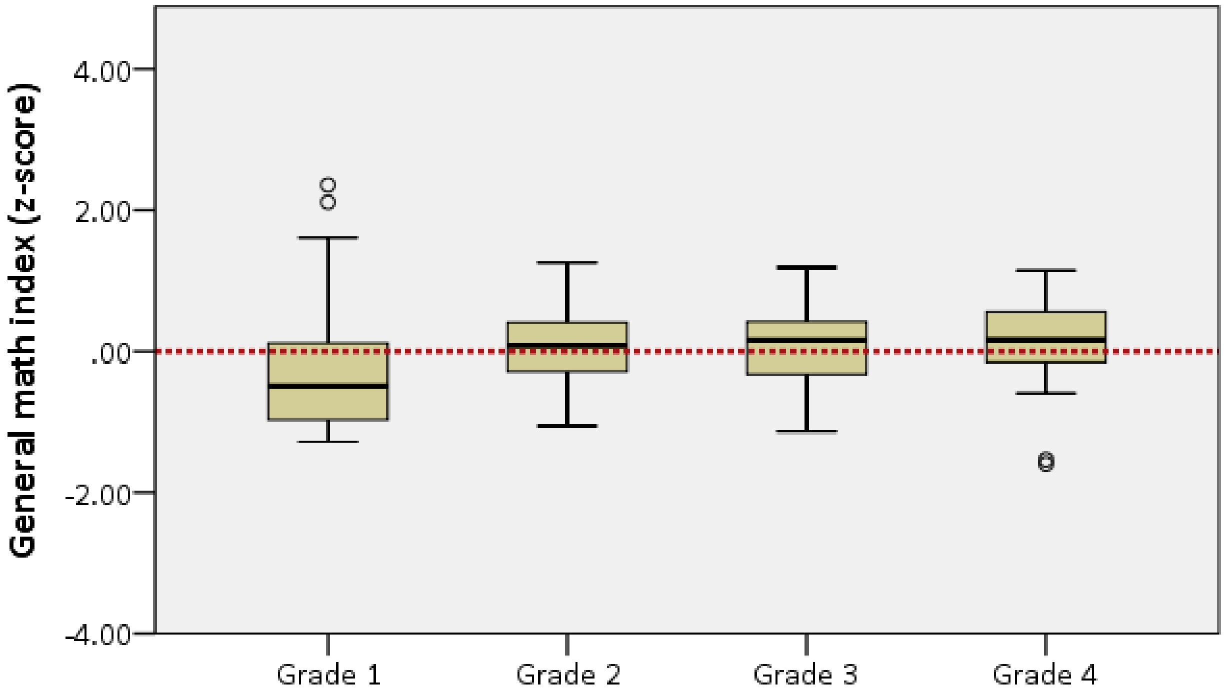
Note. [a]Linguistic tasks, [b]Mental representation tasks, [c]Contextual tasks

Figure captions

Figure 1. General math in elementary school children with autism spectrum disorder.

Figure 2. Dot plot of individual differences in general math of elementary school children with autism spectrum disorder.

Figure 3. Performance of elementary school children with autism spectrum disorder on the different domains of mathematics.



General math index (z-score)
4.00
2.00
.00
-2.00
-4.00
Grade 1
Grade 2
Grade 3
Grade 4

Figure 1

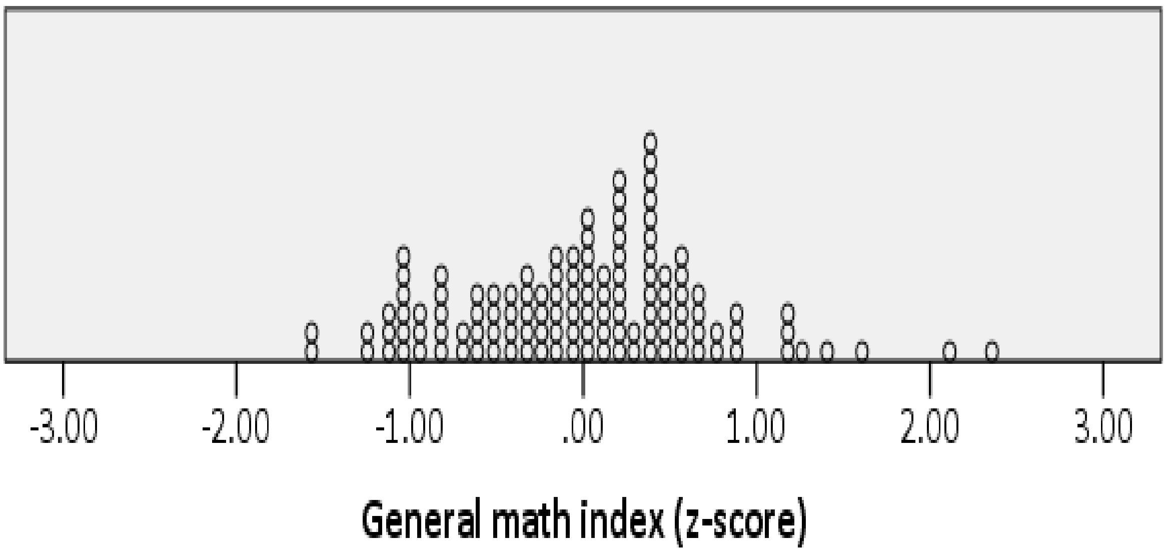


Figure 2

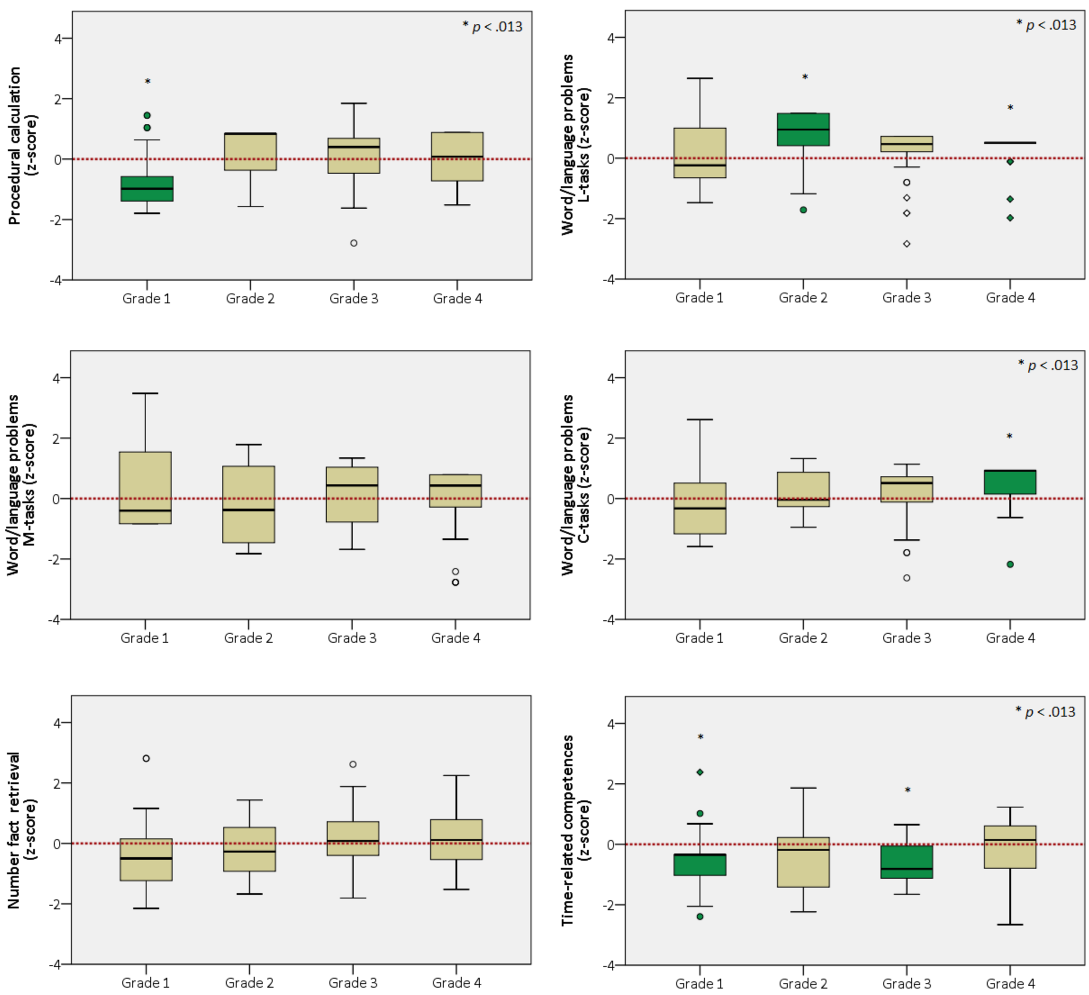

* p < .013
Procedural calculation (z-score)
Word/language problems L-tasks (z-score)
Word/language problems M-tasks (z-score)
Word/language problems C-tasks (z-score)
Number fact retrieval (z-score)
Time-related competences (z-score)
Grade 1
Grade 2
Grade 3
Grade 4

Figure 3